A SURVEY OF THE POSSUMS *TRICHOSURUS VULPECULA* AND *PSEUDOCHEIRUS OCCIDENTALIS* AND THEIR HABITATS IN FOREST AT LUDLOW, WESTERN AUSTRALIA

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ABSTRACT

Ten survey lines within the Ludlow forest were surveyed for possums on ten different nights using headtorching and counts of sighted possums. Five hundred and fifty six sightings of adult possums were recorded (282 Common Brushtail Possum, 274 Western Ringtail Possum). Estimates of the abundance of hollow trees and of the extent and floristics of the forest canopy were collected for each survey line. Analysis of the resultant data indicated that the local abundance of possums was positively correlated with the abundance of hollow trees, and with the extent of the myrtaceous canopy, implying both habitat parameters have the potential to limit local possum abundance.

INTRODUCTION

The Ludlow forest, near Capel, Western Australia is locally known for its relatively high abundance of possums. The Common Brushtail Possum (*Trichosurus vulpecula*) and the Western Ringtail Possum (*Pseudocheirus occidentalis*) are the only arboreal browsing marsupials in the southwestern forests. In 1983, the Western Ringtail Possum was accorded rare and endangered status by the Western Australian government after recognition of the marked contraction of the species range. The Ludlow population of Western Ringtail Possum is the most substantial population on land held by the Department of Conservation and Land Management (Jones *et al.* 1993a), and thus it may prove to be of considerable importance to the long-term persistence of the species.

The major aim of this study was to document the distribution and relative abundance of both possum species within the Ludlow forest. The secondary aim was to investigate associations between the patterns of relative abundance of both possum species and habitat variation. The surveys were undertaken while both authors were conducting population studies at Abba River (AB) (Western Ringtail Possum: Jones *et al.* 1993b, and Common Brushtail Possum: Hillcox, unpublished).

Results of recent studies of arboreal marsupials have generally supported the hypothesis that the level of nitrogen in leaves is a major determinant of the distribution and abundance of arboreal marsupials (Braithwaite *et al.* 1983, Kavanagh and Lambert 1990). Study of habitats occupied by the Western Ringtail Possum concluded that, in addition to leaf nitrogen levels, both the amount of canopy and the abundance of hollow-bearing trees were habitat parameters with the potential to influence the abundance of this species (Jones *et al.* 1993a).

Although both possum species at Ludlow are primarily arboreal folivores, there are considerable differences between their biology. The diet of the southern ringtail species (the Western Ringtail Possum and its closest relative, the Common Ringtail Possum of eastern Australian forests) usually consists almost entirely of myrtaceous leaves. These ringtails are specialised for a life of browsing tree leaves (e.g. teeth specialised for grinding leaves; tail strongly prehensile, Smith 1983). By comparison, the Common Brushtail Possum is a less specialised browser, and the dietary intake of leaves is supplemented with a range of other food including bark, pasture plants (How 1983) and fungi (Hillcox, unpublished).

METHODS

The following abbreviations are used throughout subsequent text: CBP: Common Brushtail Possum; WRP: Western Ringtail Possum.

The study area included the Ludlow National Park and associated forest blocks. The Ludlow forest is dominated by Tuart (*Eucalyptus gomphocephala*), which usually grows with a prominent midstorey of Peppermint (*Agonis flexuosa*). Small areas on the eastern margins are characterised by the inclusion of Marri (*Eucalyptus calophylla*) and Bull Banksia (*Banksia grandis*). Plantations of pines (*Pinus* sp.) occupy much of the area, and replaced the original Tuart forest after logging. Small areas of vegetation associated with swamps and creeklines are characterised by the presence of *Melaleuca* sp. and/or Flooded Gum (*Eucalyptus rudis*). All parts of the forest have been subject to logging at different times, and the area has a long history of use as winter grazing for cattle. The understorey is sparse or absent throughout most of Ludlow. Some areas with the Marri/Bull Banksia association tend to have a significant presence of endemic understorey species, but in the Tuart/Peppermint association groundcover is primarily of winter pasture and exotic weeds.

The location and length of the ten survey lines is shown in Figure 1. Survey lines usually followed tracks or firebreaks. Lines were each surveyed ten times between October 1991 and March 1992. The first five surveys for each line were completed during 1991. Surveys were done on nights without rain, with less than the quarter moon and during the first half of the night. A single observer (S.H.) using a headtorch walked the survey line and recorded all possum sightings. When a possum was sighted the following information was recorded: species and age class (adult/subadult), the occurrence of accompanying young and the

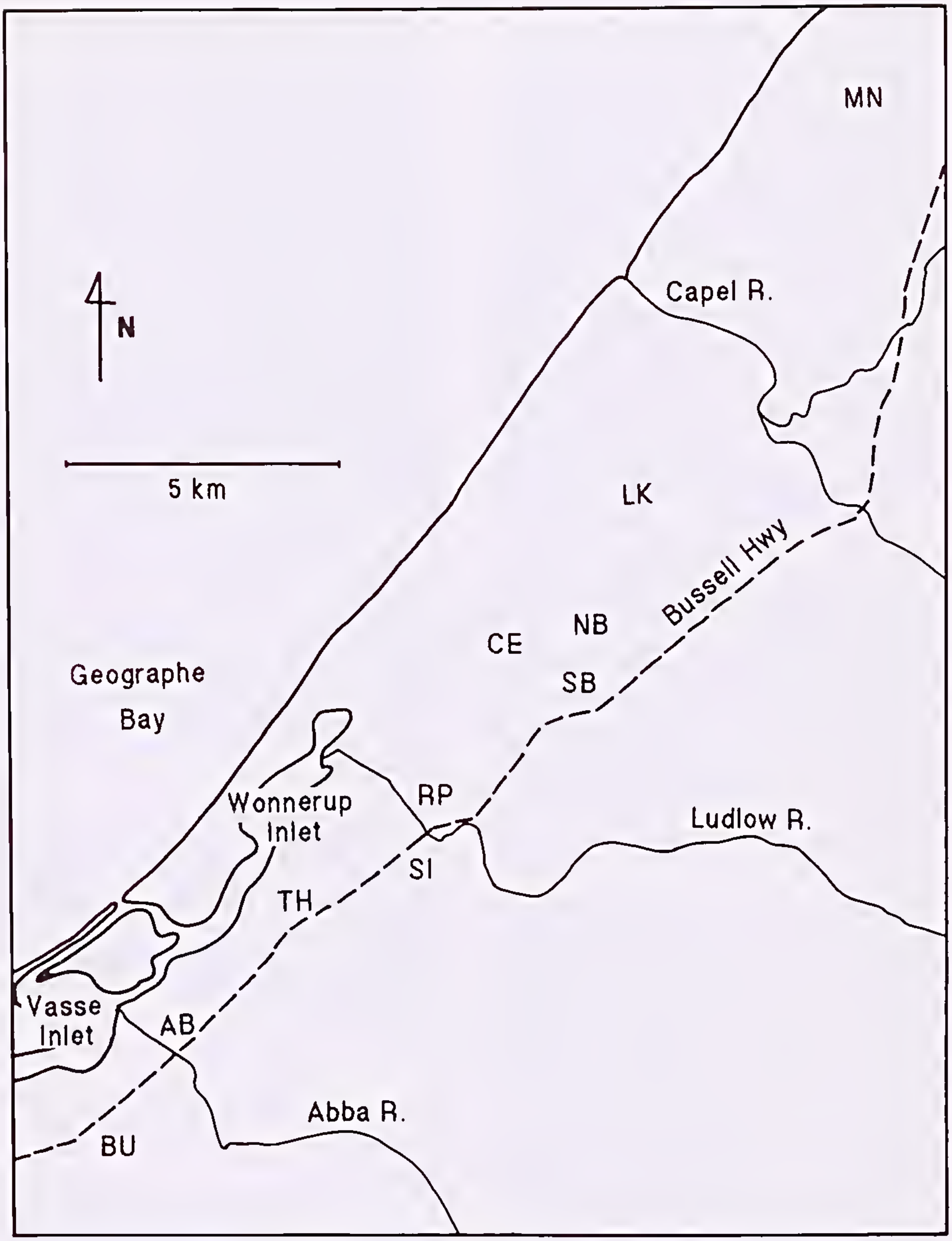

Figure 1. Map showing the location of the ten survey lines. The length of each line (in kilometres) is as follows: CE: 2.2; NB: 1.2; SI: 5.7; LK: 2.2; TH: 1.8; MN: 2.0; BU: 1.7; RP: 1.5; SB: 3.3; AB: 1.4.

location of the possum at first sighting (tree species or ground)

Descriptions of vegetation concentrated on trees (≥ 3 m) and were collected at fifteen sites (equidistant) per line, each being based on a semicircle of 15 m radius. The major strata were described in terms of height, estimated percentage canopy cover, and the relative contribution of tree species to each strata. Lines were not constrained to floristically defined vegetation units, so average tree abundances do not necessarily reflect typical vegetation associ-ations. Some rare tree species (mostly, isolated individuals of exotic species) are not included in the line summaries (Table 1). The total number of hollow-bearing trees (either alive or dead) within a 15m wide strip adjacent to the survey line was recorded. Hollow bearing trees were identified by the sighting of an obvious hollow entrance, or by the presence of limbs which had been broken off and were estimated to have a diameter of ≥ 20cm at the terminal end.

The abundance of possums was quantified as the number of sightings of adults per line (CBPS: number of adult CBP sighted, WRPS: number of adult WRP sighted, NPS: number of adult possums sighted, regardless of species). Sightings rates were calculated per kilometre because lines were of different lengths (CBPS km^{-1}: number of adult CBP sighted per kilometre of survey line, WRPS km^{-1}: number of adult WRP sighted per kilometre of survey line, NPS km^{-1}: number of adult possums sighted per kilometre of survey line.

The vegetation for each line was summarised by calculating the average percentage cover for each tree species using the highest percentage cover in any strata for each of the fifteen vegetation descriptions per line. Summary variables were thus generated to indicate the relative abundance of the tree species on each line. Two variables were generated by summing line averages: an indicator of the relative abundance of eucalypts on each line (calculated as the sum of the line average percentage cover of each eucalypt species recorded for the line) and an indicator of the relative abundance of the myrtaceous canopy on each line (calculated as the sum of the average percentage cover of Peppermint and the eucalypt species recorded for the line). Hollow tree abundance was quantified as the number of hollow-bearing trees, either alive or dead, per kilometre of survey line (HT km^{-1}).

Linear regression analysis was used to investigate associations between possum sightings rates and habitat parameters.Variables were log-transformed to improve the linearity of apparently curvilinear relationships between some pairs of raw variables.

RESULTS

Possums

The survey recorded 364 sightings of CBP (282 adult and 82 immature) and 378 of WRP (274 adult and 104 immature). There were 63 sightings of female CBP accompanied by dependent young and 84 sightings of female WRP with dependent young. Both species of possum were sighted on all lines.

For WRP, 90% of all sightings were in Peppermint and 5% in Marri. All sightings of WRP in Marri were recorded on one line (SB). All other tree species (6) were each associated with less than 1% of sightings. One sighting of a WRP on the ground was recorded. For CBP, 43% of all sightings were in Peppermint, 26% in Tuart, 14% in Marri, 6% in Jarrah and 4% in Bull Banksia. All other tree species (4) each were associated with less than 1% of sightings. Six CBP sightings were of animals on the ground.

For this set of survey lines the two species were seen with equal frequency, and 6 lines had ratios of CBPS:WRPS that did not differ significantly from 1:1 (Table 1). At TH and BU, sightings of WRP were more numerous than those of CBP (TH: $\chi^2 = 18.00$, $P < 0.005$, BU: $\chi^2 = 14.70$, $P < 0.005$). At MN and SB sightings of CBP were more numerous than those of WRP (MN: $\chi^2 = 10.26$, $P < 0.005$, SB: $\chi^2 = 7.57$, $0.005 < P < 0.010$).

Three rates of possum sightings (sightings per kilometre for CBP, for WRP and for possums, regardless of species) are available for use in

Table 1. The possum abundance and habitat variables collected (or derived) for each survey line. Tree species recorded on a line, but with a line average of less than 1% are indicated by '+', and '–' indicates the species was not present on the line. The two derived canopy variables are: EUC: an indicator of the extent of the eucalypt canopy, and MYRT: an indicator of the extent of the myrtaceous canopy.

Line	CE	NB	SI	LK	TH	MN	BU	RP	SB	AB
Possums										
CBPS	4	5	33	16	4	32	10	27	79	72
WRPS	1	5	32	23	28	12	36	23	48	66
NPS	5	10	65	39	32	44	46	50	127	138
CBPS km^{-1}	0.2	0.4	0.6	0.7	0.2	1.6	0.6	1.9	2.4	5.2
WRPS km^{-1}	0.1	0.4	0.6	1.1	1.6	0.6	2.1	1.6	1.4	4.8
NPS km^{-1}	0.2	0.8	1.1	1.8	1.8	2.2	2.7	3.4	3.8	10.0
Hollow trees										
HT km^{-1}	3.6	15.0	7.7	11.0	22.0	12.1	10.7	12.3	12.9	18.5
Canopy										
Peppermint	27	38	48	41	44	31	70	49	37	51
Tuart	12	29	32	27	15	31	8	35	41	21
Marri	–	–	13	–	+	6	–	10	26	–
Jarrah	–	+	2	–	–	8	–	–	+	–
Flooded Gum	–	–	–	–	–	–	–	6	2	+
Yate	–	–	–	–	–	–	2	–	–	–
Bull Banksia	–	–	4	–	+	3	–	1	7	–
Pine	29	+	–	+	1	–	–	+	–	–
EUC	12	29	47	27	15	45	10	51	69	21
MYRT	39	67	95	68	59	76	80	100	106	72

comparison of abundances on different lines (Table 1). Less than four possum sightings were recorded per kilometre for nine lines, but on AB possum sightings occurred at a rate of 10 per kilometre.

Habitats

Three main vegetation types were represented among the survey lines (Table 1). An association of Tuart and Peppermint was recorded for five lines (NB, LK, TH, BU, AB), pine plantation was abundant on only one line (CE), and vegetation on four lines was an association of at least three eucalypt species with Peppermint (SI, MN, RP, SB). Tuart and Peppermint were the only tree species that occurred on all lines. At AB, the survey line was within the Tuart/Peppermint association, but part of the line was adjacent to a small strip of vegetation of Flooded Gum and *Melaleuca* sp associated with the watercourse of the Abba River. Part of the BU line ran through a unique and small (c.2 ha) patch of an association of Peppermint and Yate (*Eucalyptus cornuta*).

The major habitat differences between lines are illustrated in Figure 2. The plot of the relative abundances of Peppermint and the eucalypt species emphasises the low abundance of native vegetation (specifically myrtaceous trees) in the pine plantations on CE. Two lines have relatively high eucalypt abundance and low Peppermint abundance (MN, SB), and two lines have low eucalypt abundance and higher Peppermint abundance (TH, BU). The rest of the lines have Peppermint to eucalypt ratios within these extremes. The plot of the number of hollows against the amount of the myrtaceous canopy on different lines is shown in Figure 2b. The line through the pine

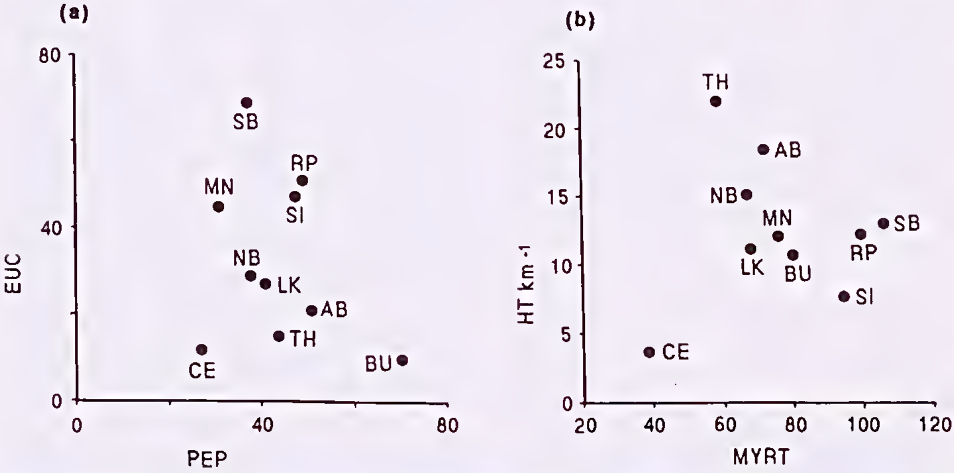

Figure 2. Scatter plots of the major habitat variables recorded for different survey lines. (a) Comparison of the extent of the eucalypt (EUC) and Peppermint (PEP) canopies, and (b), comparison of the abundance of hollow trees (HT km^{-1}) and the extent of the myrtaceous (MYRT) canopy.

plantation (CE) is further distinguished from all other sites by its very low hollow abundance.

Possum abundance and habitat variation

The relationships between the abundance of possums and canopy variables are illustrated in Figure 3. The rate of sightings of CBP was positively correlated with the abundance of eucalypts (Figure 3a), and the rate of sightings of WRP was positively correlated with the abundance of Peppermint (Figure 3b). Regression equations for the above relationships are shown in Table 2.

A positive correlation exists between possum abundance and the extent of the myrtaceous canopy (Table 2), but it is dominated by the low canopy levels for CE. There is no significant correlation between these variables for the other nine lines ($r^2 = 0.048$).

The canopy on the four lines where one possum species was more abundant than the other was characterised by more extreme values of the Peppermint to eucalypt ratio (Figure 2a). On MN and SB, CBP were more frequently sighted than WRP, and the canopy had a high eucalypt component and a low or moderate Peppermint component. On BU and TH, WRP were more common than CBP, and the canopy had a low eucalypt

Table 2. Regression equations describing relationships between possum abundances and habitat variables. Equations were derived using data for all ten lines, except as indicated.

Possums and canopy parameters

CBP (x) and eucalypt (y) abundance (Figure 3a)
$\log y = 0.88 \log x - 1.35 \quad r^2 = 0.30, 0.05 < P < 0.1$

WRP (x) and Peppermint (y) abundance (Figure 3b)
$\log y = 3.39 \log x - 5.57 \quad r^2 = 0.55, 0.0025 < P < 0.005$

Possum (x) and Myrtaceae (y) abundance
$\log y = 2.26 \log x - 3.94 \quad r^2 = 0.43, 0.01 < P < 0.025$

Possums and hollow trees

CBP (x) and hollow tree (y) abundance (Figure 3d)
$\log y = 0.90 \log x - 1.03 \quad r^2 = 0.18, 0.01 < P < 0.25$

WRP (x) and hollow tree (y) abundance (Figure 3e)
$\log y = 2.0 \log x - 2.17 \quad r^2 = 0.66, 0.001 < P < 0.0025$

Possum (x) and hollow tree (y) abundance (Figure 3f)
$\log y = 1.47 \log x - 1.28 \quad r^2 = 0.53, 0.005 < P < 0.01$

CBP (x) and hollow tree (y) abundance (excluding CE, NB, TH)
$\log y = 2.84 \log x - 2.906 \quad r^2 = 0.81, 0.001 < P < 0.0025$

WRP (x) and hollow tree (y) abundance (excluding CE, NB, TH)
$\log y = 2.22 \log x - 2.25 \quad r^2 = 0.61, 0.005 < P < 0.01$

Possum (x) and hollow tree (y) abundance (excluding CE, NB, TH)
$\log y = 2.49 \log x - 1.28 \quad r^2 = 0.90, P < 0.0001$

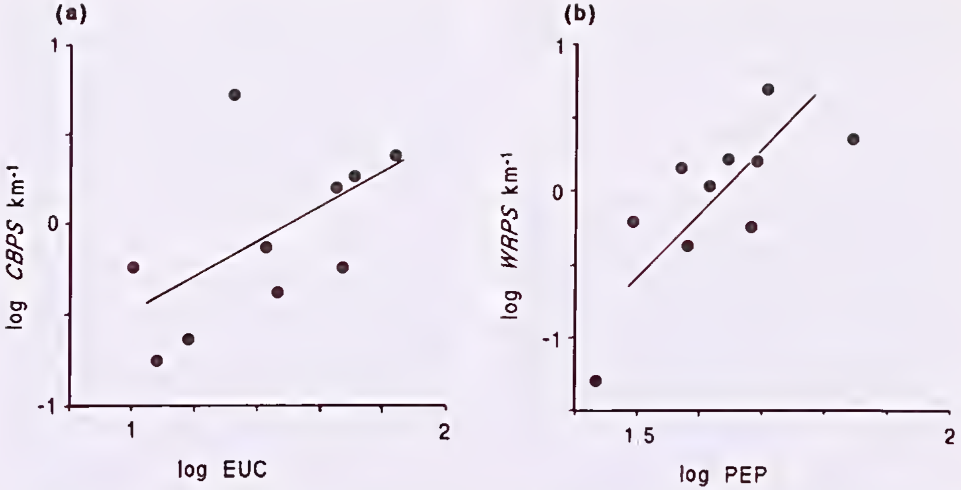

Figure 3. Scatter plots showing the relationships between (a) CBP abundance (log CBPS km^{-1}) and eucalypt abundance (log EUC) and (b) WRP abundance (WRPS km^{-1}) and the abundance of Peppermint (log PEP). Lines are those described by the relevant regression equations (Table 2).

component and a moderate to high Peppermint component.

Comparison of the number of possum sightings (Table 1) on the four lines with several eucalypt species (SI, MN, RP, SB) shows that, at SI and RP, where Peppermint abundance averaged 48–49%, sightings of WRP and CBP were equally abundant. At MN and SB, sightings of CBP were more common than WRP sightings, and the abundance of Peppermint was lower (31% and 37%, respectively).

The plots of possum and hollow abundance (Figure 4) show that generally higher abundances of possums occur on lines with higher abundances of hollow trees (regression equations in Table 2). Three lines had ratios of hollow trees per possum sighting (Figure 4d) of more than 12 (CE, NB, TH), while the other lines had 2–7 hollow trees per possum sighting. Inspection of canopy variables shows that these 3 lines have relatively low abundances of Peppermint (NB), eucalypts (TH), or of myrtaceous trees (CE and TH).

Exclusion of these three lines from analysis of the relationship between the abundances of possums and hollow trees results in correlations which are higher than those resulting from analysis of all 10 lines for CBP and for possums (NPS km^{-1}), but for WRP the relationships based on seven or ten lines are equivalent (Table 2).

DISCUSSION

The surveys showed that both possum species used all major forest types at Ludlow, and suggest that both species occur throughout the forest. However, there is

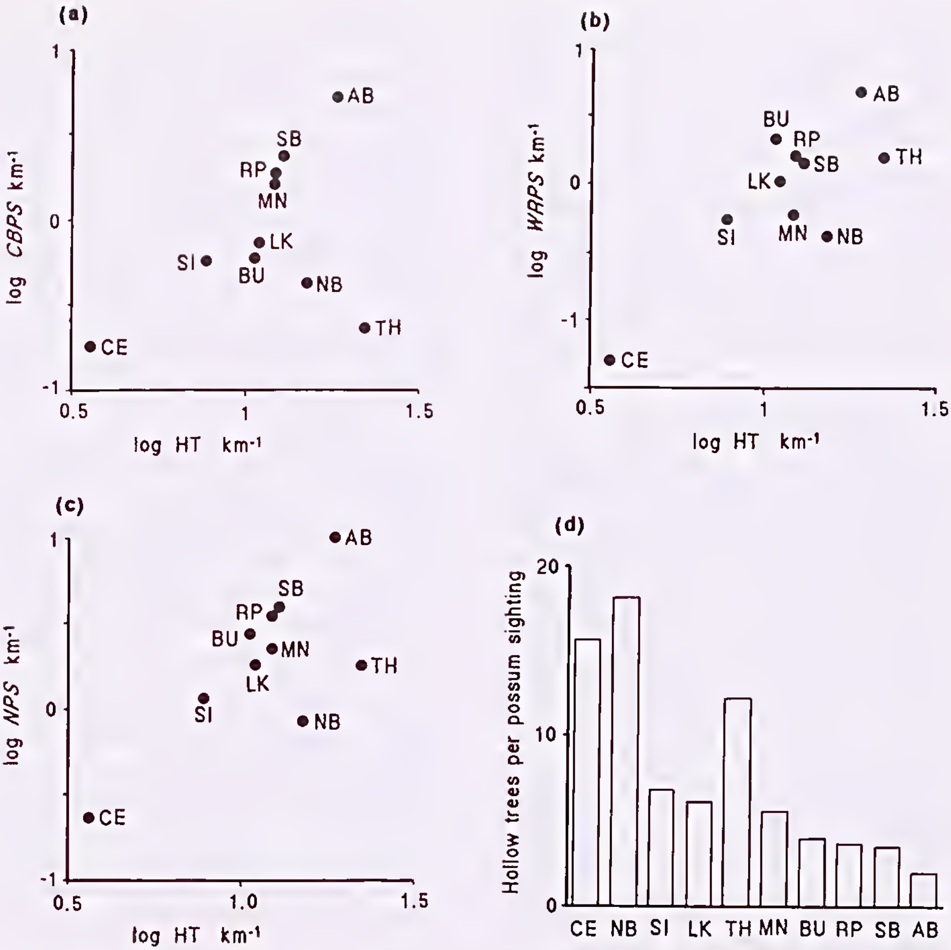

Figure 4. Relationships between abundances of possums and hollow trees. (a) CBP abundance (log CBPS km^{-1}) and hollow tree abundance (log HT km^{-1}); (b) WRP abundance (log WRPS km^{-1}) and hollow tree abundance (log HT km^{-1}); (c) the rate of possum sightings (log NPS km^{-1}) and the abundance of hollow trees (log HT km^{-1}); (d) the number of hollow trees per possum sighting (HT km^{-1}/ NPS km^{-1}) for all lines.

considerable variation in possum abundance in different areas. The abundance of both species is influenced by forest floristics. Western Ringtail Possums were the more abundant species in areas with more Peppermint, and Common Brushtail Possums were more abundant in areas with more eucalypts. Surveys of coastal Peppermint forests for possums (Jones *et al.* 1993a) showed that CBP was extremely rare or absent in forests where Peppermint grew without eucalypt species, but WRP occurred in this habitat type at a number of sites. Peppermint leaves are the staple dietary component of

WRP living in forests where Peppermint trees are common, and account for 80–100% of the diet (Jones *et al.* 1993b).

The importance of canopy abundance is primarily due to its role as a food source. However, it may have a secondary role as a refuge from terrestrial predators such as foxes or cats. Both species are known to catch and eat possums (Jones *et al.* 1993b, and unpublished observations). The decline of WRP populations has been most extensive in inland areas where canopies tend to be more dispersed than in coastal and near-coastal habitats. Possums living in areas with open canopies may need to use ground travel to access feeding and rest sites, while those living in more dense canopies may access more of the resources within the home range via the canopy.

In this set of Ludlow survey lines, three lines had abundances of hollow trees which were greater than 13 hollow trees per kilometer of survey line. Two of these lines had few possums compared to the number of hollow trees (NB and TH) (Figure 4d), and the third (AB) had the highest possum abundances recorded for any site. Inspection of the canopy variables for these three lines (Table 1) shows on AB the abundance of Peppermint is relatively high (51%) compared to the other two lines (38% on NB and 44% on TH).

On CE, hollow trees were relatively rare, but the ratio of hollow trees per possum sighting was similar to those for NB and TH. Of the lines dominated by the Tuart/Peppermint association, CE and NB have the lowest Peppermint abundances, and CE and TH have the lowest abundances of myrtaceous trees. These data suggest that on CE, NB and TH, where hollow trees are abundant, the canopy parameters limit the site's possum carrying capacity. The positive correlations for the subset of seven lines suggests that, for most of the Ludlow forest, hollow tree abundance is an important habitat variable for possums, and it has the potential to limit a habitat's possum carrying capacity.

The southern ringtail possums (the Western and the Common Ringtail Possums) rest during daylight hours in dreys (nests) built in trees from twigs and other vegetation, or in tree hollows when available (McKay 1983). A recent study of WRP (Jones *et al.* 1993b) found that dreys were only abundant in near-coastal Peppermint forests, and dreys were rare in more inland areas, where hollows were the usual rest site. The patterns of possum and hollow abundance for the Ludlow survey lines indicate that Ludlow is similar to the inland habitat-types where both species usually rest in hollows (Inions 1985).

Several studies of possums and their habitats (Braithwaite *et al.* 1983, Smith and Lindemayer 1988, Jones *et al.* 1993a, and this study), between them, identify four habitat parameters likely to be of importance in defining habitat quality in terms of possum populations. Forest floristics, the abundance of foliage and its nutritional quality, and the abundance of hollow trees all appear to have the potential to limit possum abundance. A field study of possums (WRP and CBP) at Perup showed that deeper tree hollows were used more frequently than were shallower ones (Inions *et al.* 1989), suggesting that the quality of available hollows is probably another important habitat variable. Results of an analysis of WRP abundance in different habitats (Jones *et al.* 1993a) concluded that the nitrogen content of leaves was the most important habitat variable for WRP, and that extent of canopy cover and the abundance of hollow trees were also potentially important. The general trends in possum abundance and habitat variation at Ludlow provide further support for the importance of habitat parameters relating to the extent and floristics of the forest canopy, and to the availability of hollow trees.

For our set of Ludlow survey lines canopy abundances appear to be a major limit to the possum carrying capacity on three lines (CE, NB, TH), while on other lines, hollow tree abundance appears to impose a more important limit. Further study is required to test the hypothesis that the major determinant of possum carrying capacity at Ludlow is based on the relative quantities of the resources of food and shelter. Accurate description of the relationships between possum, canopy and hollow tree abundances could provide land managers with quantitative guidelines for maintaining or increasing an area's habitat quality for possums.

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REFERENCES

BRAITHWAITE, L.W., DUDZINSKI, M.L. AND TURNER, J. 1983. Studies on the arboreal marsupial fauna of eucalypt forests being harvested for wood pulp at Eden, N.S.W. II. Relationships between the fauna density, richness and diversity and measured variables of the habitat. *Australian Wildlife Research* 10: 231–247.

HOW, R.A. 1983. Common Brushtail Possum. p 147–8 in: *The complete book of Australian Mammals*, R. Strahan (ed). The Australian Museum and Angus and Robertson, Sydney.

INIONS, G. B. 1985. The interactions between possums, habitat, trees and fire. Honours thesis, Australian National University, Canberra.

INIONS, G.B., TANTON, M.T. AND DAVEY, S.M. 1989. Effect of fire on the availability of hollows in trees used by the Common Brushtail Possum, *Trichosurus vulpecula* Kerr, 1792, and the Ringtail Possum, *Pseudocheirus peregrinus* Boddaerts, 1785. *Australian Wildlife Research* 16: 499–58.

JONES, B.A., HOW, R.A. AND KITCHENER, D.J. 1993a. A field study of *Pseudocheirus occidentalis*–(Marsupialia, Petauridae). Part I: Distribution and habitat. *Widlife Research* 21:175–87.

JONES, B.A., HOW, R.A. AND KITCHENER, D.J. 1993b. A field study of *Pseudocheirus occidentalis* (Marsupialia: Petauridae) Part II: Population studies. *Widlife Research* 21:189–201.

KAVANAGH, R.P. AND LAMBERT, M.J. 1990. Food selection by the Greater Glider, *Petauroides volans*: is foliar nitrogen a determinant of habiat quality ? *Australian Wildlife Research* 17: 285–99.

MCKAY, G.M. 1983. Common Ringtail Possum. p 126–7 in: *The complete book of Australian Mammals*, R. Strahan (ed). The Australian Museum and Angus and Robertson, Sydney.

SMITH, A.P. AND LINDENMAYER, D. 1988. Tree hollow requirements of Leadbeater's Possum and other possums and gliders in timber production Ash forests of the Victorian Central Highlands. *Australian Wildlife Research*, 15: 347–62.

SMITH, M.J.1983. Ringtails and the larger gliders: p124–5 in: *The complete book of Australian Mammals*, R. Strahan (ed). The Australian Museum and Angus and Robertson, Sydney.